Human Factors Engineering
NASA - Johnson Space Center

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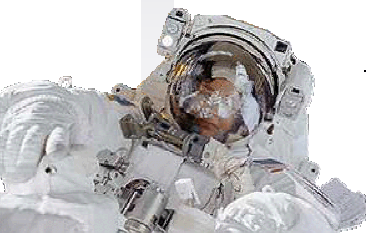
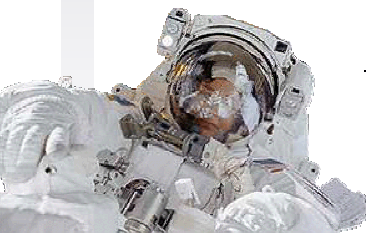
November 8, 2002



Agenda

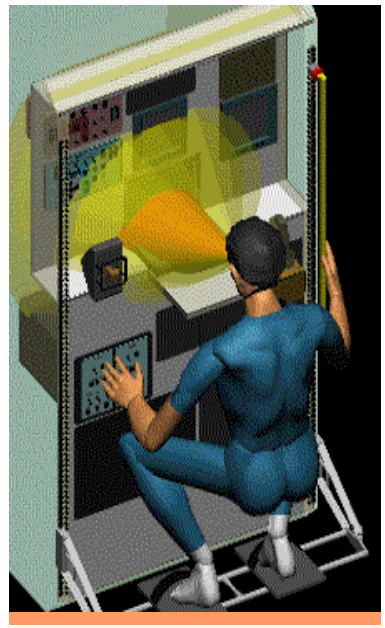
-- JSC is the coordinating center for NASA Space Human Factors Engineering

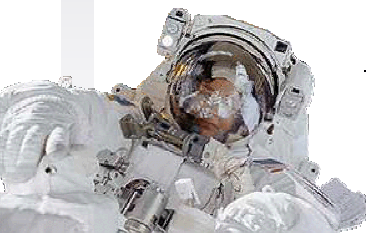
- What Is SHFE and Why Is It Important?
- SHFE Project Details
- Current and Future Work



What Is SHFE?

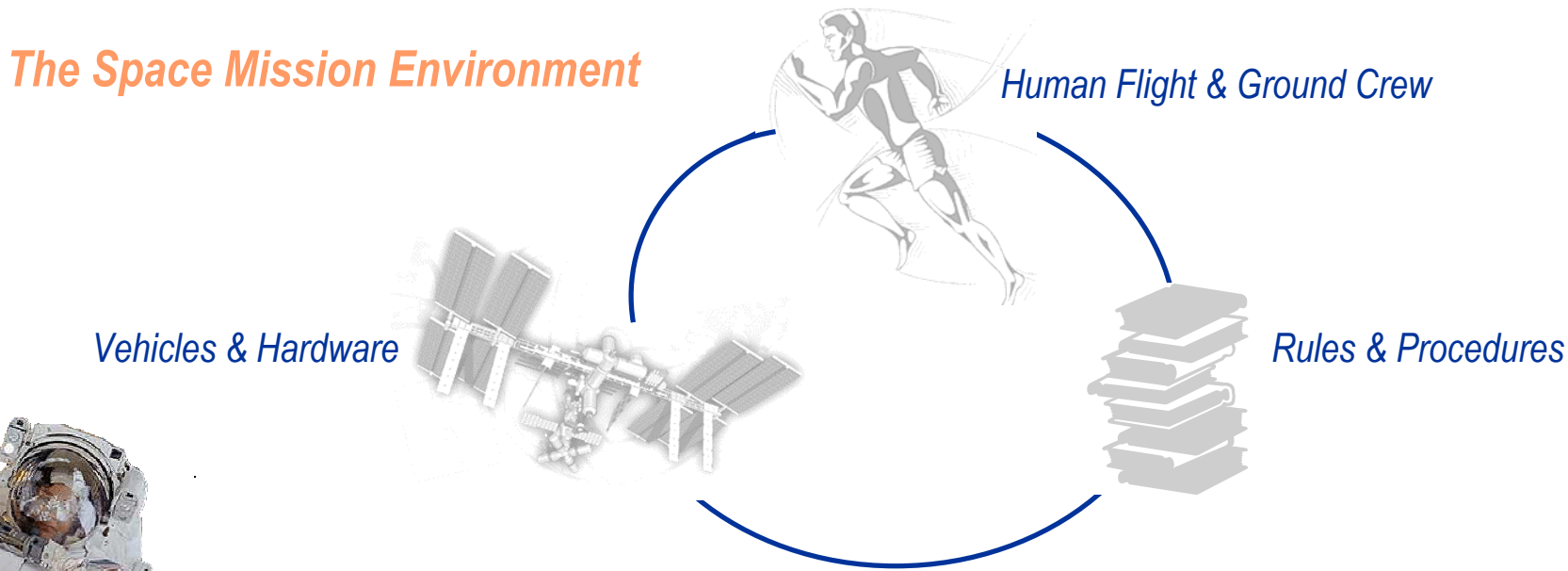
- **Assessment and Modeling of Human Performance**
  - Anthropometrics and biomechanics
  - Cognitive performance
  - Perception (visual, auditory, etc.)
  - Proficiency (training)
  - Workload and planning/scheduling
  - Team performance (interaction, skills maintenance, etc.)
- **Systems and Habitability Design**
  - Human-system interaction
  - Habitable volume and architecture
  - Environmental factors (noise, lighting, temperature, etc.)
  - Social factors (privacy, collaboration, recreation, etc.)
  - Human-systems interface design
  - Habitability design requirements
- **Information Management and Communication**
  - Data collection, analysis, and distribution
  - Crew autonomy
  - Human-information interfaces
  - Information exchange

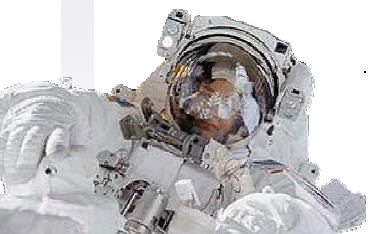




What Is SHFE?

- Approach: Define and apply human performance information to hardware design and mission operations
- Results: ***Maximize system performance*** **and** ***reduce mission risk***





SHFE Activity Paths

Customer pull

AHST/SHFE
(Funded by Code U)

STS and ISS
(Funded by Code M)

Technology push

NRA Grants
- Selection managed by HQ
- Formal external peer review

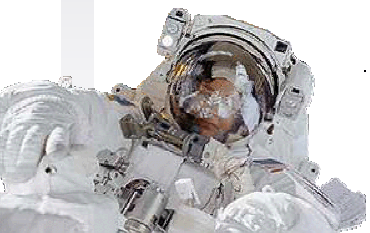
Technology Development Projects (TDPs)
- Selection managed by JSC
- External review performed by STWG

Development
- Verify requirements
- Apply analysis to requirements
- Hab systems concept designs

Operations
- Internal volume configuration
- Operational habitability
- Payload labels
- Lighting analysis

1 2 3 4 5 6 7 8 9

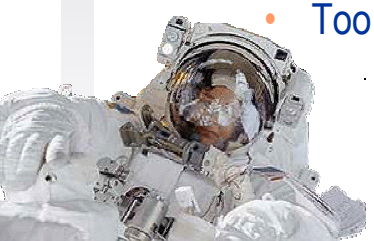
Technology/Science Readiness Level (TRL / SRL)



Why Is SHFE Important?

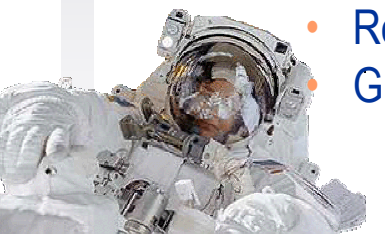
- **Specific SHFE opportunities for ISS risk reduction and productivity improvements:**

  - Workload, crew activity scheduling
    - More important as length of duration increases
  - Emergency response
    - Adequacy of Caution and Warning System notifications
    - Ease of use/understanding of emergency procedures
  - Human-computer interfaces
    - Unix environment differences as compared to standard MS Windows
    - Multi-layered menu scheme
    - Situational awareness can be impacted by current display design
    - Must be correlated with procedures
  - Procedures
    - Too long, confusing, time consuming



Why Is SHFE Important?

- **Specific SHFE opportunities for ISS improvements *(continued):***
  - Stowage and inventory management
    - Nonproductive time spent looking for items
    - Lack of adequate stowage locations for the amount of equipment and supplies onboard
  - Acoustic environment
    - Reduce potential for permanent or temporary noise-induced hearing loss
  - Code Standardization
    - Labeling
    - Location codes
  - Body restraints
    - Robotics Operations
    - Glovebox Operations



Resources

NASA JSC Human Factors Expertise

NASA (SF)
2 Ph. D - HFE
8 MS / BS HFE,
Engineering, Architecture

NSBRI
5 Ph.D - HFE
2 MS Engineering

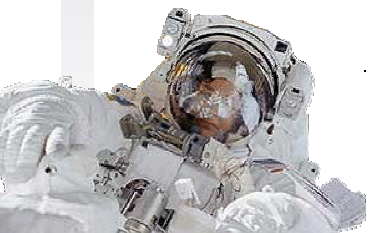
Engineering, Safety
ISS, Crew Office
3 Ph. D - HFE
8 MS Engineering

Johnson Engineering
1 MD
4 Ph.D - HFE
40 MS / BS HFE / Engineering

JSC Facilities

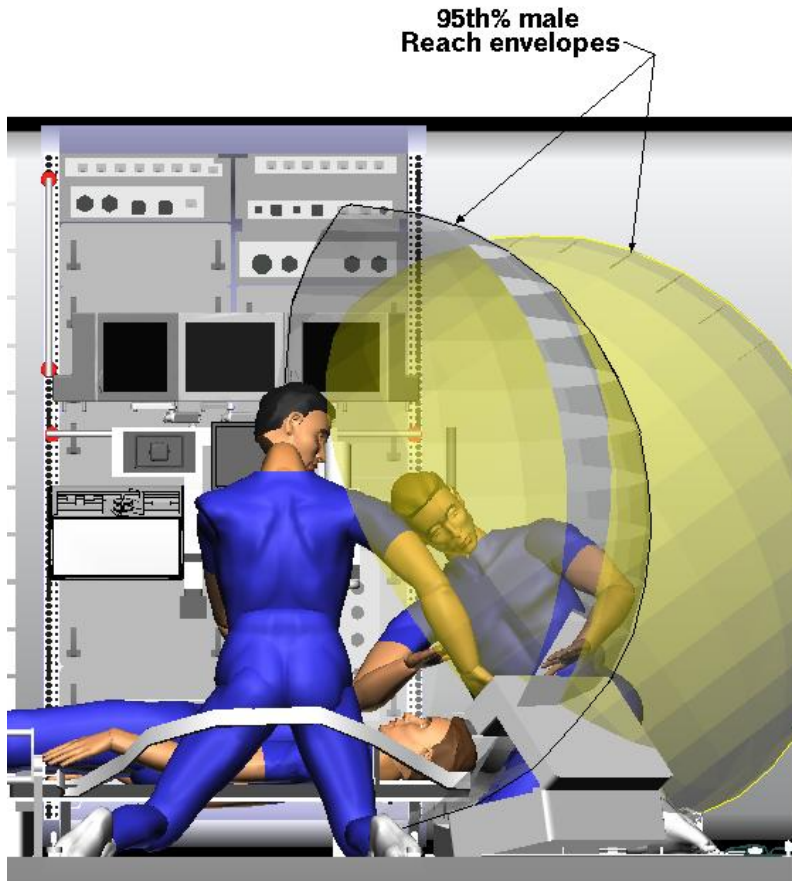
- **Anthropometry & Biomechanics Facility**
  - Data Collection, Models, Data Bases
    - Anthropometry data base
    - linear measurements and 3-D scans
  - Biomechanics
    - Force and Strength data collection
    - Linear and 3-D strength measurement

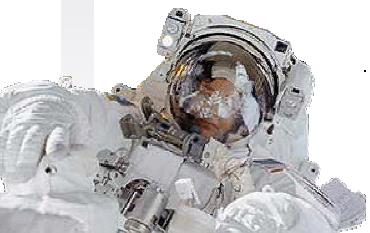
- **Usability Testing and Analysis Facility**
  - Physical interfaces
    - Posture, restraints, reach, access
  - Cognitive interfaces
    - HCI
    - Procedures



JSC Facilities

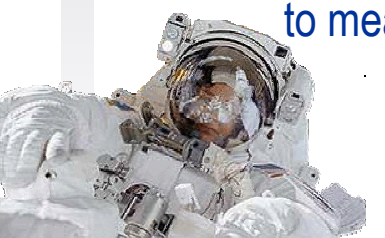
- **Graphics Research and Analysis Facility**
  - Human Modeling for 0-G
    - Neutral body posture
    - Reach and access, visibility, interference
  - Lighting in Space
    - Light sources, shadows, reflections
    - Camera properties
- **Lighting Environment and Test Facility**
  - Data collection for lighting models
    - Light sources, shadows, reflections
    - Camera properties





Why Is SHFE Important?
Success Stories

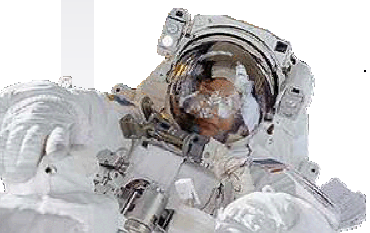
- **Improved crew usability for ISS hardware design**
  - Airlock: improved access to critical controls and co-located sequential controls
  - Stowage rack and trays: match human strength capabilities
  - Portable light: prevented touch temperature hazard
  - Labels and icons: phosphorescent for emergency equipment and egress
  - Stowage constraints: reduced illumination issues
  - Onboard stowage: protected operational volume for crew exercise and emergency health care
- **Operational benefits from SHFE NRAs**
  - Crew impact loads: data used to define design requirements for ISS interior structure
  - Strength, endurance, and range of motion in EMU-suited subjects: used for EVA task planning
  - Psychophysical studies of video quality: used by international standards organizations to measure effects of video compression



Why Is SHFE Important?
Success Stories

- **Lighting / viewing models**
  - High-fidelity models of external lighting saved ISS Program Office $4M by eliminating the need for additional lights
  - Pre-flight orbital lighting and crew viewing assessments have contributed to the success of robotics operations during ISS assembly and maintenance tasks

- **NASA-STD-3000, Man-Systems Integration Standards (MSIS)**
  - Captures knowledge about designing for humans in space environments
  - Distributed to individuals, schools, and companies throughout the world
  - Excellent reference for human factors requirements; used by flight programs
  - Acknowledged need for review and re-design of this important document



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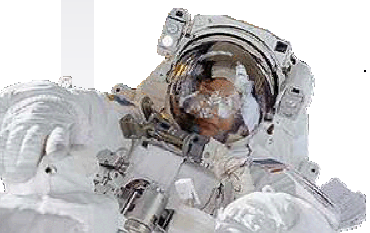
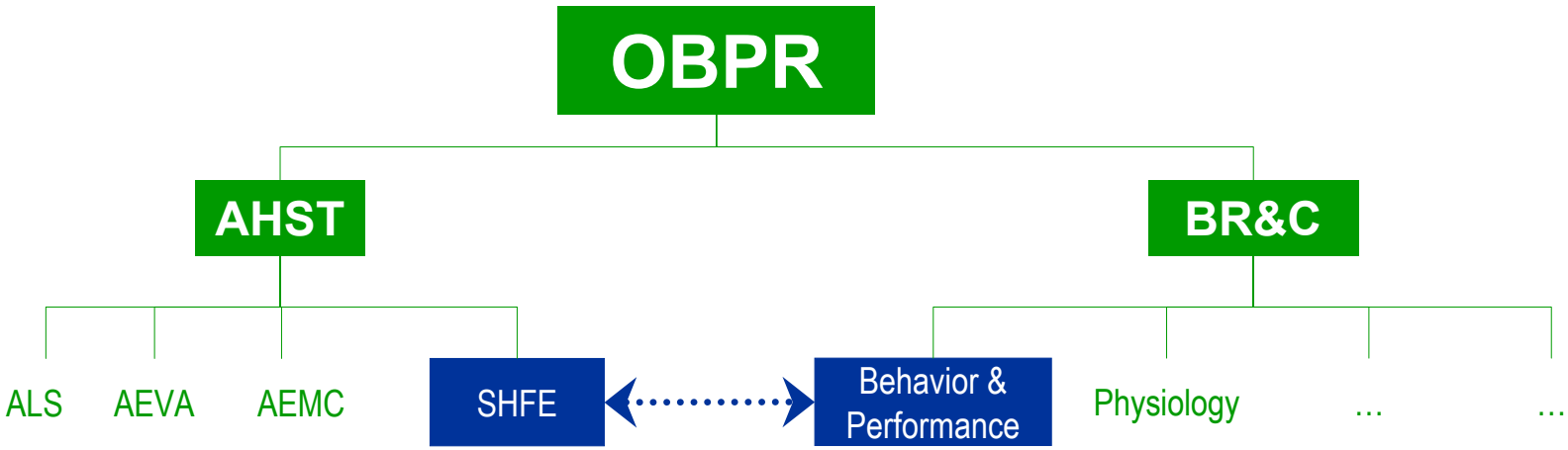
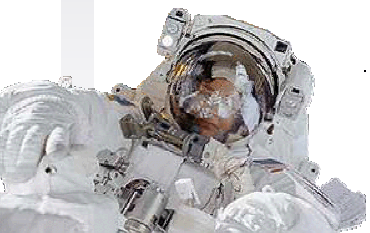


SHFE Project



- **SHFE Management Team**
  - Project Manager and Deputy Manager at JSC
  - Deputy Manager for SHFE Activities at ARC
  - Discipline Coordinating Scientist (NSBRI, at JSC)



Guiding Documents

AHST PCA

AHST Program Plan

SHFE Project Plan

STWG

Implementation Plan

Critical Path Roadmap (CPR)

NRA Solicitations

TDPs

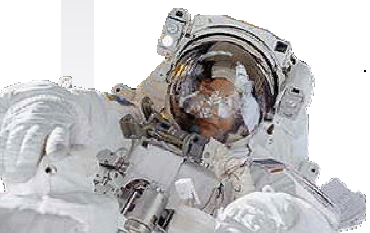
NSBRI

Internal and external inputs

PIs

SHFE Solutions

Answer CPR critical questions

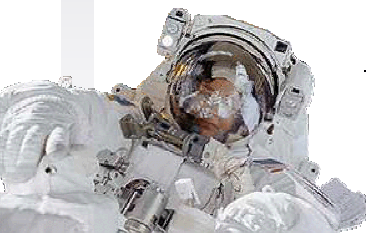


TDPs: technology development projects
STWG: Science and Technology Working Group

Guiding Documents
SHFE Content in CPR

Risk #20: Human performance failure because of human-system interface problems and ineffective habitat, equipment design, workload, or in-flight information and training systems

- Critical Questions
  - What ***information and communication*** systems, methods, and tools will support a crew's ability to meet mission objectives? (6.09)
  - What ***workload*** schedule(s) will enhance crew performance? (6.10)
  - What methods of ***assessing human performance*** will be most effective? (6.11)
  - What factors in ***systems and habitat design*** will best enhance crew's ability to live and work on long-duration space missions? (6.12)
  - What computational ***models*** best ***predict*** human performance on space missions? (6.22)



Over 100 detailed deliverables are defined and being baselined in CPR

Interfaces

SHFE interfaces with many human factors communities

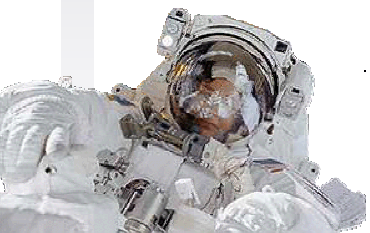
External Interfaces

- Academia
- Industry
- DoD
- Other government agencies (FAA, NIOSH, etc.)

S H F E

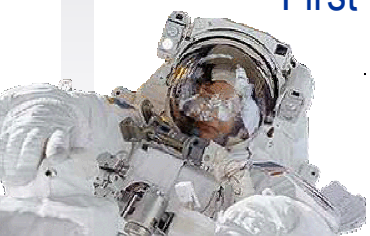
Internal Interfaces

- Behavior and Performance
- ALS/AEMC/AEVA
- Medical Ops
- Mission Ops
- Advanced EVA
- Crew Offices
- Human-Centered Computing (Code R)
- Engineering
  (e.g., simulation, automation and robotics, flight crew systems)
- Flight Programs



Interface Examples

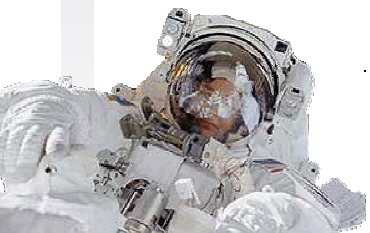
- Mission Operations Directorate
  - SHFE NRA work on anomaly response communication patterns in mission control
  - SHFE participating in crew scheduling tiger team
- Behavior and Performance
  - Members of B&P IPT
  - PIs working in both SHFE and B&P (e.g., Stuster and Woods)
- Medical Operations
  - Emergency medical procedures project
  - Exercise physiology and biomechanics
- Academia
  - Collaborative projects in work (e.g., Advanced 3-D Visualization NRA grant, Wayne State/JSC)
  - NSBRI
  - First Research Opportunity Workshop at JSC in December 2002



Interface Examples

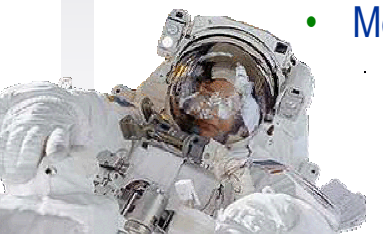
- Academia, continued
  - Convened second Biennial Space Human Factors Workshop
    - Held January 23-24, 2002
    - 95 participants represented academic and NASA community
    - Proceedings: http://www.dsls.usra.edu/dsls/meetings/shfp/proceedings/Contents.pdf

  - Monthly PI telecons conducted to maintain contact and forum discussions
  - Every other year contact with PIs through the Bioastronautics Workshop – JSC, January 14-15, 2003



External Guidance

- Science and Technology Working Group (STWG)
  - Members represent academia, industry, and military
    - 3 new members invited to join in January 2002
  - Includes broad spectrum of human factors expertise:
    - Human-computer interfaces
    - Habitability
    - Military and security
    - Health and safety
    - Automotive industry
    - Complex systems maintenance
    - Knowledge management
    - Anthropometrics/Biomechanics
    - Human-Robotic Systems interactions
    - Spaceflight Operations
  - Provides expert external guidance
    - Short- and long-term strategy
    - Knowledge gaps
    - Merit review of internal mid-range projects and proposals



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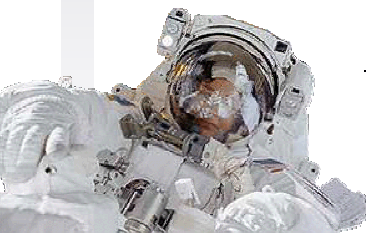
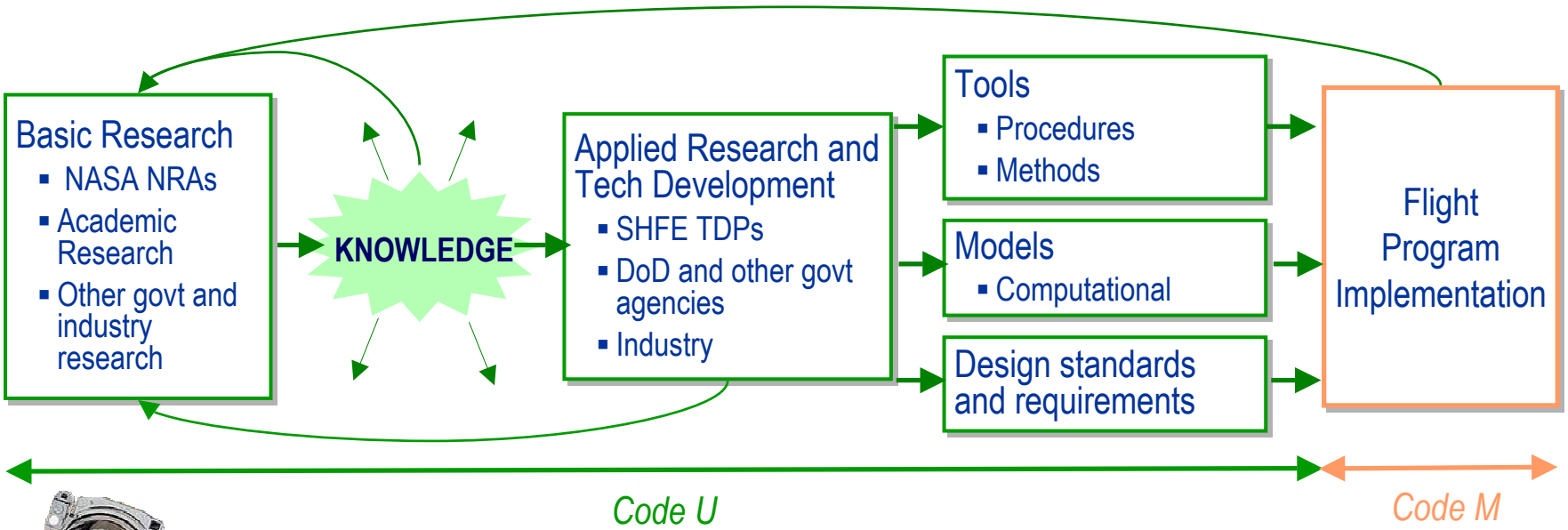
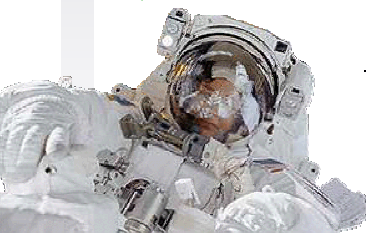


Current and Future Work

SHFE → **Reduced risk (CPR)**
Better productivity → **Greater success**
More science

- Brings **near-term** benefits to **current** flight programs
- Answers critical questions for **future** long-duration space missions

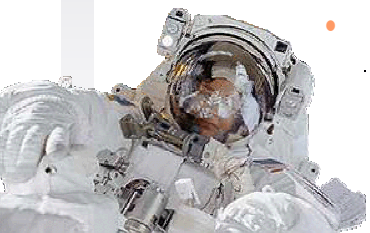




Current Work

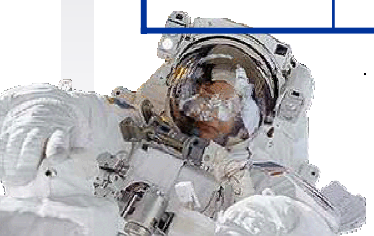
- **NRA Grants**
  - 7 in progress
  - 4 selected but not started
  - 1 flight investigation just selected

- **Topics include:**
  - Model development
    - Error prediction
    - Maintenance
    - Mission control communication
    - On-orbit crew loads
    - On-orbit lighting
  - Augmented and virtual reality
    - Teleoperation and telepresence
    - Augmented reality for training
  - Sensory and cognitive characterization
    - Human centered visual displays
    - Kinesthetics
    - Utility of immersive displays
    - Eye tracking technology
    - Work practices
  - Physical data analysis
    - Crew reactions



Current NRA Grants

PI	Institution	Due	Title
Neumann	USC	Mar-03	Augmented Reality for Space Flight
Zamorano	Wayne State U.	Jan-03	The development and human factors analysis of advanced 3-D visualization for telepresence
Nitzan	SRI	Dec-02	Telepresence human factors for glove box experiments
Badler	U Penn	Sep-03	Crew Task Simulation for Maintenance, Training, & Safety
Schlegel	U Oklahoma	Dec-03	Integrated Crew Performance Assessment & Training
Ellis	ARC	Sep-03	Kinesthetic compensation for sensorimotor rearrangements
Watson	ARC	Sep-03	Human Centered Visual Displays
McCann	ARC	Dec-05	Development of a Crew-Systems Concept for Vehicle Health Management in Next Generation Spacecraft
Schlegel	U. Oklahoma	Dec-05	Development and Evaluation of RMS Operator Proficiency and Training Effectiveness Metrics
Le	SoftMax	Dec-05	Automatic Speech Recognition in Noisy Environments
Maida	JSC	Dec-05	Enhanced Lighting Techniques and Augmented Reality to Improve Human Task Performance



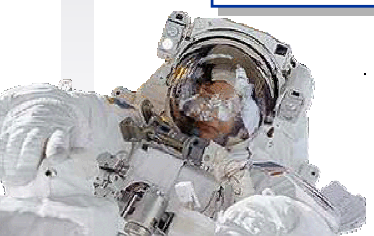
TDP Selection Process

Mid-Range TRL Internal Projects

SHFE identifies CPR gaps and prioritizes → STWG reviews needs → SHFE requests proposals for specific needs

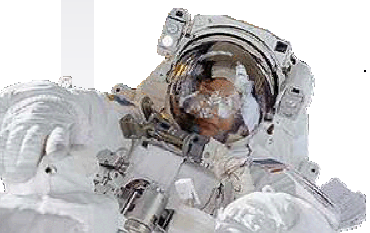
Proposals submitted → SHFE evaluates proposals → STWG reviews proposals for merit

SHFE recommends projects to fund → AHST and OBPR/BRD approval → **Projects funded** → STWG reviews projects for continuation



Current Work

- **Technology Development Projects (TDPs)**
  - 9 mid-range TRL projects now in progress:
    - 3-D anthropometrics tools
    - Crew sleep scheduling tool
    - Restraints systems study
    - Imagery systems for improved habitability
    - Malleable human-computer interfaces
    - Emergency medical procedures usability
    - Physiological effects of habitability factors
    - Lessons learned in requirements verification
    - SHFE database



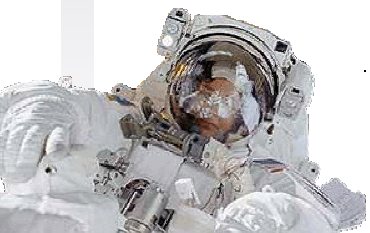
Current TDPs

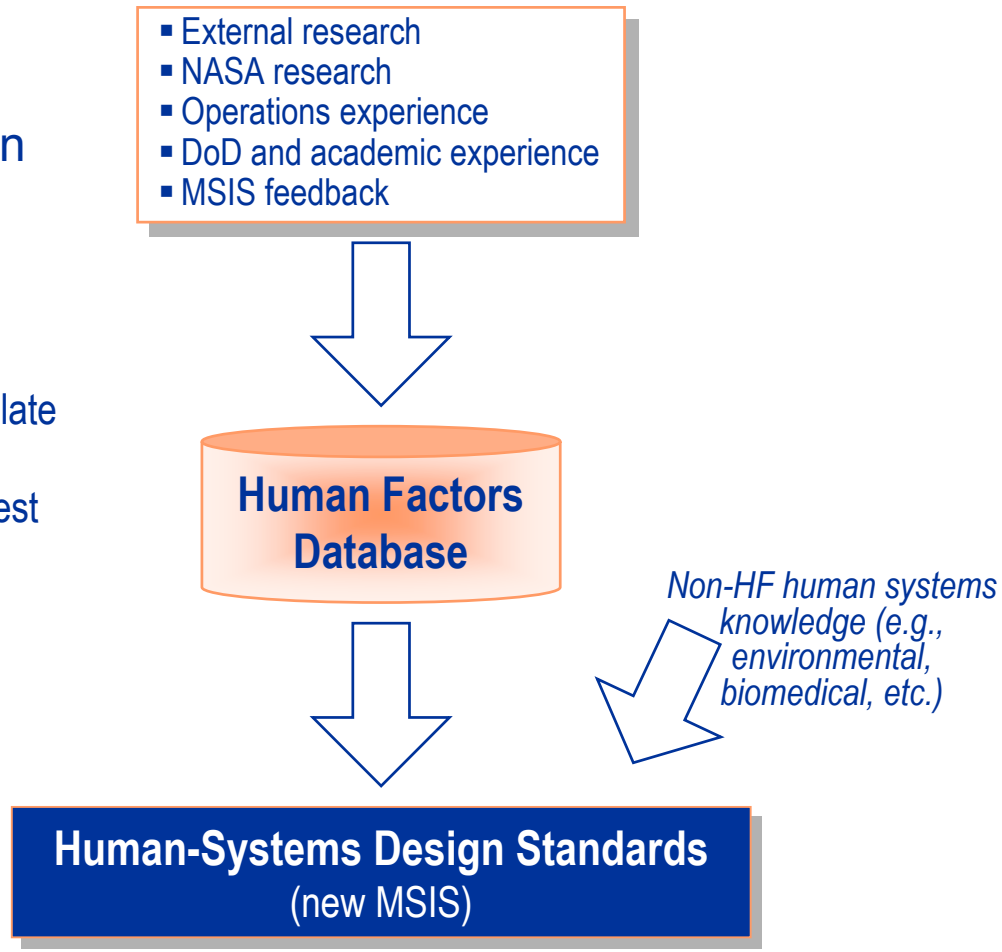
- 9 in work: 1 ends FY02, 1 ends FY03, and 7 end FY04

Project	Expected Products
SHFE database	Central location for tracking research results and gaps for SHFE
Restraints	Detailed requirements and design concept for crew restraints based on STS and ISS experience
Emergency medical procedures	Usability evaluation of ISS medical procedures; comparison with procedures from analogs such as Antarctic and military; methodologies for more usable procedures
3-D anthropometrics	Software to process digital surface maps of human bodies for vehicle and hardware ergonomic analysis
Physiological index of habitability	Quantitative assessment of physiological and performance responses to habitability and other factors
Crew sleep scheduling	A scheduling tool based on a mathematical model of performance
HF requirements process	Revisions to HF requirements implementation and verification processes based on lessons learned
Imagery systems	Validated requirements, technical specs for multipurpose imagery displays for exercise enhancement and habitability / psychological purposes
Malleable human interfaces	Toolkit and rationale for multi-purpose HCI interface design

Future Work

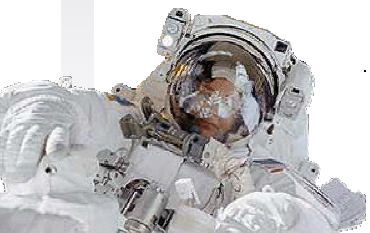
- Design standards and requirements
  - Key method of putting human factors knowledge and technology to use
  - Current document, MSIS, is inadequate
    - Severely out of date (last updated late 1980s)
    - No regular process for infusing latest knowledge
  - Reinventing MSIS planned





Summary

- SHFE is critical to success of current and future human space missions
- SHFE Project has well-defined processes
  - for selecting and managing research, and
  - for applying results to operations
- SHFE Project is well-connected to extramural human factors community
- Current and future projects not only provide near-term benefits to ISS, but also address human factors concerns for future space exploration



Next Steps for SHFE

- Continuation of clarification of SHFE aims and objectives
  - Implementation plan
  - Critical Path Roadmap or other detailed objectives
- Continue funding of new mid-range technology development projects
  - FY'03 projects have been reviewed and approved
- SHFE database and MSIS reinvention
  - Translate results of SHFE basic and applied research into flight programs
  - One of highest priority over next few years
- Need better methods for improving "success rate" of NRA and TDP projects.